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WHOLE-GRAIN RICE FLAVOR ASSOCIATED WITH ASSORTED BRAN COLORS

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ABSTRACT

Recognition of the health benefits of whole-grain and pigmented bran rice has resulted in their increased consumption. Bran contributes fiber, minerals, vitamins and an array of phytonutrients to the diet. Understanding flavor differences arising from bran pigmentation helps consumers choose the best rice for their use. Ten panelists trained in descriptive analysis developed 25 descriptors to describe whole-grain rice flavor and evaluated the flavor of 22 rice samples with white, light-brown, dark-brown, red and black bran. Brown rice had more intense grainy/starchy, cooked cereal and corn/popcorn/buttery flavors. Black rice was higher in oily, dark-berry, medicinal and smoky/burnt flavors. Red rice had greater intensities for beany, animal/wet dog and earthy flavors. The darker cultivars tend to have more bitter taste and astringent mouthfeel. This lexicon enhances the understanding of flavors associated with rice bran color.

PRACTICAL APPLICATION

Whole-grain rice is unpolished or unmilled rice with the bran layers retained. The bran layer has many nutrients that are removed during polishing (milling). Because of the health benefits of keeping the bran layer intact, whole-grain rice has experienced an increase in demand worldwide. Milled-rice flavor has been characterized, but whole-grain rice has a different flavor profile due to the bran. This new whole-grain rice flavor lexicon describes the flavor attributes and differences between bran color and types of whole-grain rice.

INTRODUCTION

Rice is a staple food in the diet for many countries with milled rice being the most commonly consumed. Increased consumer awareness of the health-protective benefits of whole-grain rice, following the U.S. Food and Drug Administration extension in 2008 of the whole-grain health claim to include brown rice, has driven a marked increase in its consumption in the U.S.A. One cup of cooked whole-grain rice contributes two of the three recommended servings of whole grains, as well as 15 vitamins and minerals, including B vitamins, iron and zinc (Moon 2010). Other known health-beneficial compounds in whole-grain rice include several classes of antioxidants such as γ-oryzanols, tocols and polyphenols (Finocchiaro *et al.* 2007). Antioxidants are protective against oxidative damage, which has been implicated in a range of diseases, including cancer and cardiovascular disease (Goffman and Bergman 2004). Rice cultivars with red and purple/black bran contain 20 times more phenolic compounds than cultivars with white or light-brown bran rice (Goffman and Bergman 2002 as cited in Goffman and Bergman 2004) which can impact flavor. Much of the current research reports the healthful aspects of pigmented rice, but reports nothing about the flavor.

Nutritional value alone will not drive consumer's acceptability of whole-grain rice. An understanding of aroma and flavor is important for discerning consumer demand. In the case of pigmented whole-grain rice, the high phenolic content can contribute to bitterness and astringency detracting from its appeal. Scented whole-grain rice can vary widely in the intensity of its characteristic popcorn aroma. Thus, whole-grain rice cultivars, scented and unscented, with

various pigmented bran, are expected to show wide variation in aroma and flavor. Continued growth of the whole-grain market will depend in part upon industry having an understanding of this variation in aroma and flavor attributes of the whole-grain rice cultivars, which will allow for the selection of cultivars for specific or appropriate markets.

This study was undertaken to develop a descriptive lexicon with reference standards for describing the aroma and flavor properties of whole-grain rice. Our lexicon was built upon previously published rice flavor and aroma lexicons (Goodwin *et al*. 1996; Meullenet *et al*. 1999; Park *et al*. 2001; Limpawattana and Shewfelt 2010) used primarily for milled white rice and scented rice. Differences that bran color plays in flavor perception were described.

MATERIALS AND METHODS

Lexicon Development

A group of 10 panelists trained in descriptive analysis techniques (Meilgaard *et al*. 2007) was used for this study. Upon selection as a panel member, each panelist received 24 h of basic sensory and descriptive sensory analysis instruction covering introduction to sensory perception, attribute identification, attribute intensity and development of terminology. Then they learned the attributes of the products they would be working on and practiced with the sets of attributes until they became proficient, precise and accurate (about 90 h of practice). Orientation and training procedures were similar to those reported by Koppel and Chambers 2010, Civille *et al*. 2010; Talavera-Bianchi *et al*. 2010. All panelists had at least 1 year and up to 20 years of experience in evaluating descriptive flavor of a variety of foods prior to the development of these descriptors. The panelists had experience evaluating milled-rice flavor attributes.

During descriptor development in a conference room setting, the panelists described flavors in nine commercial rice samples consisting of various bran colors. They were served two to three whole-grain rice cultivars per day during six sessions. Some samples were repeated during this stage of the lexicon development to aid in further development of certain descriptors. The rice samples (600 g) (2.25:1 water : rice) were cooked to completion in Breville RC 19XL (Breville USA, Rancho Dominguez, CA) rice cookers and then held for 10 min before serving. Cooked rice samples were served in pre-warmed (120C) glass custard bowls, insulated by fitted Styrofoam (James River Corp., Corte Madera, CA) bowls and covered with 125-mm diameter watch glasses. Each sample had a three-digit code to identify it as described in Champagne *et al*. (1999). First, each panelist lifted the watch glass slightly to smell the rice, repeated this several times as necessary and recorded observed aromas. Next, each panelist tasted the rice several times and recorded observed flavors. Nabisco Unsalted Tops Saltine Crackers (Kraft Foods Global, Inc., Northfield, IL) and filtered water were provided to cleanse the palate after each sample, as well as having at least 5 min between samples.

After evaluating each rice sample, there was discussion and a list was made of all aromas and flavors observed. A lexicon was compiled from all of the panelists' input. References that best represent the flavor descriptors were chosen.

After the descriptors were developed, they were tested by the panelists using the descriptors to evaluate the attributes using a universal intensity (15-point numerical) scale (Meilgaard *et al*. 2007) during an additional six sessions in a climate-controlled room containing 12 individual booths with sodium vapor lighting. Scoring was done on computers with the Compusense Five System 4.8 (Guelph, Ontario, Canada). Eight samples were scored, with some samples presented once and some twice. Reference samples for each attribute were available for review at these sessions.

During discussions after these sessions, five descriptors were changed as well as the order of appearance. After acquiring raw rice bran and rice hulls, the former descriptor bran/hulls and woody/lumber were rearranged and enhanced to make bran/hay/straw and hulls/woody. Also, the musty reference related better with the cardboard descriptor, and the earthy stood alone as an attribute. During this phase, brown jasmine rice was introduced, which had a popcorn flavor. The panelists agreed that corn and popcorn would be best combined. When the buttery flavor appeared, it was thought to be more like buttery popcorn. Therefore, these three descriptors were combined to make "corn/popcorn/buttery."

After evaluating intensities of the eight rice samples, it was determined that the terms animal/wet dog, smoky/burnt, brothy/meaty and rancid/oxidized were present consistently enough to be included in the list of descriptors on the ballot and not used as write-ins. With the group's input, 25 attributes were defined to describe whole-grain pigmented rice along with references for identifying the flavors (Table 1).

Testing the Lexicon

In order to test the lexicon over a wide range of whole-grain rice cultivars, 22 cultivars were evaluated. Rice samples were purchased from local grocery stores (12 samples) and produced by the United States Department of Agriculture-Agricultural Research Service rice experiment station (10 samples) in Beaumont, TX (Table 2). The rice grown at the experiment station in 2009 was stored as rough rice under refrigerated conditions until ready for shelling, just prior to delivery to the Southern Regional Research Center in New Orleans, LA. The cultivar or brand, bran color, source and cooking ratio (water weight : rice weight) are described in Table 2.

TABLE 1. FLAVOR AND AROMA LEXICON FOR PIGMENTED WHOLE-GRAIN RICE

Flavor attribute	Definition	Reference
Grainy/starchy (oatmeal/wheat/flour)	A general term used to describe the aromatics in the flavor associated with uncooked grains such as corn, oats and wheat. It is an overall grainy impression characterized as sweet, brown, sometimes dusty, and sometimes generic nutty or starchy.	Ground mixture of rice flour, white flour, yellow cornmeal and oatmeal, birdseed
Cooked cereal (cooked wheat/oatmeal cereal/wild rice)	Aromatic associated with cooked mash, hot cereal aromas. i.e., cooked bulgur wheat, cooked oatmeal and cooked wild rice.	Cooked bulgur wheat, cooked oatmeal and cooked wild rice
Sweet aroma	A sweet impression such as cotton candy, caramel or sweet fruit (not berry) that may appear in the aroma or aromatics.	Cotton candy, Kraft caramel
Corn/popcorn/buttery	The sweet aromatics of the combination of corn kernels, corn milk, and corn germ found in canned yellow creamed-style corn. A dry, dusty, slightly toasted and slightly sweet aromatic in the flavor that can be specifically identified as popcorn also includes buttered popcorn.	Canned yellow creamed-style corn, air-popped popcorn, butter
Nutty	Aromatic associated with nuts or nut meats. i.e., pecans, almonds, peanuts, hazelnuts, sesame seeds.	Pecans, almonds, peanuts
Bran/hay/straw	Aromatic associated with bran, raw wild rice (includes hay and straw).	Rice bran, raw wild rice, Timothy hay, straw
Hulls/woody	Woody aromatic associated with cut wood (fresh or aged) also includes rice hulls.	Wood chips, rice hulls
Oily (waxy/soapy)	Aromatic associated with long-chain fatty acids such as wax, crayon or unscented soap.	Wax, crayon or unscented soap.
Darkberry	A fruity aromatic note associated with blueberries, blackberries or currants (gooseberries).	Fresh blueberries and blackberries
Dairy	A general term associated with the aromatics of pasteurized cow's milk. Most apparent just before swallowing.	2% milk at room temperature
Beany/lentils	Aroma associated with cooked beans, lentils or other legumes	Cooked red or white beans
Grassy/green bean	A green, slightly earthy, slightly sweet aroma/flavor including grassy and fresh green bean aroma/flavor.	Fresh green beans, freshly cut grass
Brothy/meaty	Aromatic associated with boiled meat, soup, stock. Weak meaty note.	Beef bouillon cube dissolved in water
Cardboard/musty (brown paper)	Aromatic associated with wet cardboard packaging. A flat aromatic that is similar to white bond paper or brown kraft paper that includes glue or paste. Also, aromatic characteristic of damp basement	Brown kraft paper, Elmer's white glue or Scotch glue stick, cardboard, wet cardboard
Earthy	Aromatic characteristic of dirt or soil, also geosmin or MIB	2 ppb soln geosmin and MIB, garden soil
Eggy/sulfury	Aromatic associated with boiled eggs or sulfur compounds	Boiled eggs
Animal/wet dog	Aroma characteristic of an animal such as fur or bedding. Also, aromatic associated with wet dog hair or wet wool.	Damp dog hair or damp wool
Medicinal (phenol/camphor)	Aromatic associated with band-aids, disinfectant (sporicidin) or cooling medicinal aroma. i.e., Campho-Phenique or iodine.	Campho-Phenique or iodine
Smoky/burnt	Perception of any type of smoke flavor or burnt toast	Liquid smoke
Rancid/oxidized	Aromatic associated with oxidized fats and oils such as old oil.	Linseed oil
Sour/acidic	Sour aromatic or taste associated with vinegar (Lea & Perrin's), citrus or fermented vegetative matter.	Dilute rice vinegar, Lea & Perrin's
Sweet taste	Basic sweet taste associated with sugar	2% sugar solution
Bitter taste	Taste on tongue stimulated by solutions of caffeine or quinine	Caffeine solution
Water-like/metallic	Aromatics and mouthfeel of the minerals and metals commonly associated with tap water. This excludes any chlorine aromatics that may be perceived.	Cooked cream of wheat cereal held for 2 h.
Astringent	The chemical feeling factor on the tongue, described as puckering/drying and associated with tannins or alum.	Alum solution

MIB, methylisoborneol.

TABLE 2. LIST OF RICE SAMPLES, BRAN COLOR, SOURCE AND COOKING RATIO USED IN THIS STUDY

Rice cultivar	Bran color	Source	Cooking ratio (wt : wt)
6360 (PI177224)	White 1	Experiment station	2.125:1
Dichroa (PI231644)	White 2	Experiment station	2.125:1
Brown Sweet Rice	White 3	Grocery store	2.25:1
Wells (PI612439)	Light brown 1	Experiment station	2.125:1
79 (PI406073)	Light brown 2	Experiment station	2.125:1
365 Organic Short Grain Brown Rice	Brown 1	Grocery store	2.25:1
365 Organic Long Grain Brown Rice	Brown 2	Grocery store	2.25:1
Texas Long Grain Brown Rice	Brown 3	Grocery store	2.25:1
Lundberg Short Grain Brown Rice	Brown 4	Grocery store	2.25:1
Rice Select Texmati Organic Brown	Brown 5	Grocery store	2.25:1
Rice Select Texmati Brown Rice	Brown 6	Grocery store	2.25:1
Lundberg Brown Basmati Rice	Brown 7	Grocery store	2.25:1
DJ53 (PI403091)	Brown 8	Experiment station	2.125:1
Firooz (PI584569)	Brown 9	Experiment station	2.125:1
Lotus Foods Bhutanese	Red 1	Grocery store	2.25:1
Woodlands Himalayan	Red 2	Grocery store	2.25:1
Bulk (Clor12300)	Red 3	Experiment station	2.125:1
IITA 119 (PI458466)	Red 4	Experiment station	2.125:1
Mitak (PI373786)	Black 1	Experiment station	2.125:1
Lua Chua Chan (PI154344)	Black 2	Experiment station	2.125:1
Lundberg Black Japonica Rice	Black 3	Grocery store	2.25:1
Lotus Foods Forbidden	Black 4	Grocery store	2.25:1

Portions of each rice sample (600 g) were cooked to completion in Breville RC 19XL or Aroma ARC-787D-1NG (Aroma Housewares Co., San Diego, CA) rice cookers and then held for 10 min before serving. Samples were taken from the rice cookers as described by Champagne *et al.* (1999). Cooking was staggered so that samples were analyzed at 20-min intervals. This was not done during descriptor development, because discussion times could not be predetermined. The water weight : rice weight ratios used for the rice purchased in grocery stores were calculated from the cooking instructions on the labels. Slightly less water was used on the samples grown on the experiment station based on experiment station recommendations. Whereas water-to-rice ratio affects cooked rice texture, Bett-Garber *et al.* (2007) observed that milled-rice flavor was not significantly affected by water to rice ratio. An exception was water-like/metallic in one aromatic sample, where the "ideal" water to rice ratio was significantly more intense than the "too much" water and the "too little" water.

Statistical Analysis

Ward's cluster analysis (SAS Enterprise Guide 4.2, SAS Institute, Inc., Cary, NC) was performed on the means of individual rice samples to group rice samples based on the flavor descriptors. Least square means was performed in conjunction with analysis of variance using Proc Mixed (SAS Enterprise Guide, v. 4.2) to compare the bran means. Cluster means were evaluated with F values. Correlations between flavor attributes were estimated by pairwise method in JMP v.8.0 (SAS Enterprise Guide, SAS Institute, Inc.).

RESULTS AND DISCUSSION

Lexicon

A lexicon with 25 flavor attributes to describe whole-grain rice was developed (Table 1). This lexicon was based on previously published rice lexicons for milled rice (Goodwin *et al.* 1996; Meullenet *et al.* 1999; Park *et al.* 2001) and that of Limpawattana and Shewfelt (2010) for different rice types, which included smoky, barny, buttery, rancid, waxy, earthy and green for the six brown and pigmented rice samples in their sample set. Our lexicon introduces darkberry, beany, brothy/meaty and medicinal attributes. Correlation analysis of the 25 attributes showed that several were highly correlated ($r > 0.80$). Darkberry was positively correlated with medicinal (0.85), smoky/burnt (0.87) and oily (0.87). Grain/starchy and cooked cereal were also positively correlated (0.80). Table 3 lists the correlation analysis of the 25 attributes.

Some of the descriptors used by others and ourselves for milled rice were modified to better describe the flavor of the whole-grain cultivars. Popcorn and corn flavors were separate flavor descriptors in Bett-Garber *et al.* (2007) and Champagne *et al.* (2010). In this lexicon, we combined corn flavor and popcorn flavor and added buttery flavor to make up corn/popcorn/buttery, because there were so few

TABLE 3. CORRELATION ANALYSIS OF 25 AROMA/FLAVOR ATTRIBUTES

	G/S	CK CER	SWT AR	CRN/POP	NUT	B/H/S	HL/WD	Oily	DRKBRY	Dairy	Beany	G/GB
G/S	1											
CK CER	0.7964	1										
SWT AR	**–0.5397**	–0.4148	1									
CRN/POP	**0.4979**	**0.4992**	–0.0656	1								
NUT	0.2001	–0.1121	–0.2186	0.0915	1							
B/H/S	**–0.6100**	**–0.5259**	–0.0526	–0.2158	–0.0574	1						
HL/WD	–0.2370	**–0.4539**	0.1850	0.0372	0.3907	0.1438	1					
Oily	**–0.5357**	**–0.5706**	–0.3622	**–0.5275**	0.1119	0.2189	0.1647	1				
DRKBRY	–0.7005	–0.6991	**0.5353**	–0.7079	–0.1520	0.3062	0.1006	0.8713	1			
Dairy	0.3605	**0.5848**	0.0042	0.2817	–0.1157	–0.3397	–0.1680	**–0.5965**	**–0.5062**	1		
Beany	–0.1922	–0.1926	–0.2947	**–0.6407**	0.2235	0.2425	0.2879	0.2610	0.2719	–0.0837	1	
G/GB	0.2939	0.4076	0.0438	0.3715	0.1388	–0.3876	0.0147	–0.3878	**–0.4890**	**0.4517**	–0.0477	1
BR/MTY	–0.2039	**–0.4623**	–0.0079	**–0.5613**	0.1324	0.1344	–0.0101	0.6950	0.6735	**–0.6110**	0.1782	**–0.4686**
CRD/MSTY	–0.3284	–0.3237	–0.2233	**–0.4898**	0.0190	0.3351	–0.2156	0.3857	0.3477	–0.3569	0.3871	–0.1504
Earthy	–0.2834	**–0.5619**	–0.1165	–0.3577	0.2892	0.1738	**0.5426**	**0.5079**	0.3696	**–0.5729**	**0.4834**	–0.0985
EG/SF	–0.1961	–0.0772	–0.1791	**–0.4333**	0.3072	0.1402	–0.0364	**0.4939**	0.4148	–0.2273	**0.4288**	–0.3093
AN/WD	–0.3916	**–0.4810**	–0.1417	–0.7802	0.1468	0.2343	0.0370	**0.5634**	**0.5997**	–0.4083	**0.5292**	**–0.4556**
MEDC	–0.7354	**–0.6495**	**0.4690**	**–0.6512**	–0.2273	0.3358	–0.1309	0.7454	0.8461	–0.4102	0.1414	–0.3080
SM/BRN	**–0.6318**	–0.7583	0.2833	–0.7894	0.0046	0.3726	0.1683	0.7647	0.8655	**–0.5142**	0.4076	**–0.4801**
RAN/OX	–0.2674	–0.3779	0.1054	–0.3740	0.2892	0.0615	0.3513	**0.5911**	**0.4718**	–0.3242	0.3915	–0.1400
SR/AC	–0.3302	**–0.5971**	0.2148	**–0.4946**	–0.0222	–0.1283	0.2149	**0.4346**	**0.4792**	–0.3595	0.1082	–0.1959
SWT TST	–0.2655	–0.0590	0.1297	0.2489	0.1945	0.2270	0.2757	–0.1916	–0.1816	0.4121	–0.0444	0.1810
BIT TST	–0.6894	**–0.5191**	0.2499	–0.3804	–0.1942	**0.5108**	0.0622	**0.4943**	**0.5851**	**–0.5755**	0.2008	–0.3454
WL/MET	–0.1263	0.2586	–0.0383	–0.2558	–0.2765	–0.0322	**–0.6329**	0.0822	0.1173	0.2365	–0.0268	0.1617
AST	**–0.6227**	**–0.6253**	0.2629	**–0.5251**	–0.1772	**0.4796**	0.0979	**0.6202**	0.7579	**–0.4578**	0.3127	–0.1766

	BR/MTY	CRD/MSTY	Earthy	EG/SF	AN/WD	MEDC	SM/BRN	RAN/OX	SR/AC	SWT TST	BIT TST	WL/MET
G/S												
CK CER												
SWT AR												
CRN/POP												
NUT												
B/H/S												
HL/WD												
Oily												
DRKBRY												
Dairy												
Beany												
G/GB												
BR/MTY	1											
CRD/MSTY	0.3653	1										
Earthy	0.4073	0.**5123**	1									
EG/SF	***0.5590***	**0.4711**	0.2808	1								
AN/WD	0.6982	**0.5283**	**0.4378**	0.6795	1							
MEDC	***0.5962***	**0.4538**	0.2239	0.3600	**0.6028**	1						
SM/BRN	0.7376	**0.5165**	**0.4896**	0.4214	0.7481	0.8005	1					
RAN/OX	**0.5222**	0.3695	**0.4979**	**0.5938**	**0.4551**	**0.4279**	**0.4296**	1				
SR/AC	***0.5396***	0.3687	**0.5719**	0.2566	**0.5366**	**0.5407**	**0.6092**	**0.4531**	1			
SWT TST	**–0.4282**	–0.1622	–0.0112	–0.0952	–0.1893	–0.1282	–0.1297	–0.2155	–0.0865	1		
BIT TST	0.3100	**0.4709**	0.3454	0.3011	0.3265	**0.5832**	**0.5282**	0.1537	0.2531	–0.1696	1	
WL/MET	0.2675	0.1560	–0.3161	0.1650	0.0159	0.3191	0.1179	–0.0281	–0.0129	–0.2450	0.0094	
AST	***0.5734***	**0.5012**	**0.4263**	0.3104	**0.4683**	0.7366	0.7347	**0.4521**	0.3283	–0.0926	**0.5514**	0.1503

Data that are bold, bold underlined and underlined indicate significance at $P < 0.05$, $P < 0.01$ and $P < 0.001$, respectively.

G/S, grainy/starchy; CK CER, cooked cereal; SWT AR, sweet aroma; CRN/POP, corn/popcorn/buttery; NUT, nutty; B/H/S, bran/hay/straw; HL/WD, hulls/woody; Oily, oily(waxy/soapy); DRKBRY, darkberry; Dairy, dairy; Beany, beany/lentils; G/GB, grassy/green bean; BR/MTY, brothy/meaty; CRD/MSTY, cardboard/musty; Earthy, earthy; EG/SF, eggy/sulfury; AN/WD, animal/wet dog; MEDC, medicinal; SM/BRN, smoky/burnt; RAN/OX, rancid/oxidized; SR/AC, sour/acidic; SWT TST, sweet taste; BIT TST, bitter taste; WL/MET, water-like/metallic; AST, astringent.

examples of aromatic whole-grain rice that had any one of the attributes in the development set of rice samples. Because the brown-colored bran samples in the test samples were typically high in this attribute, it would have been advisable to determine the utility of separating this descriptor into corn and popcorn/buttery. Sewer/animal from the milled-rice lexicon was replaced with eggy/sulfury, animal/wet dog and brothy/meaty characteristics in the whole-grain rice. In the results from this study, eggy/sulfury significantly correlated with animal/wet dog (0.68) and brothy/meaty (0.56); animal/wet dog correlated with brothy/meaty (0.70). These descriptors were distinct, but the chemical compounds that produce these aromas may result from similar processes during production, drying or cooking; or, another explanation may be that the aromatic compounds that cause these flavors have different nuances based on their concentrations or threshold effect. For example, one panelist's brothy/meaty may be perceived as animal/wet dog to another. Calculating correlations between descriptors for individual panelists revealed that 60% of the panelists did not have correlations between these descriptors. One panelist had high correlations (>0.80) between all three descriptors. One panelist had high correlations (0.89) between eggy/sulfury and animal/wet dog. Two panelists had moderate correlations (between 0.60 and 0.69) between animal/wet dog and brothy/meaty. Another descriptor, hay-like/musty in milled rice became cardboardy/musty, earthy and bran/hay/straw in whole-grain rice. The bran/hay/straw attribute was not significantly correlated with cardboardy/musty (0.34) or with earthy (0.17). Cardboardy/musty and earthy were moderately correlated (0.51). Three panelists had high individual correlations (>0.70) between cardboardy/musty and earthy flavors. The other panelists had correlations that were much lower.

TABLE 4. FLAVOR ATTRIBUTE MEANS AND *F* VALUES OF CLUSTER GROUPINGS

Flavor attribute	Cluster 1 (Brown)	Cluster 2 (Red)	Cluster 3 (Black)	*F* value
Darkberry	0.29	1.58	3.18	233.46
Smoky/Burnt	0.46	1.23	1.56	36.01
Medicinal	0.50	0.87	1.39	27.79
Oily	0.73	1.22	1.55	22.39
Corn/popcorn/buttery	1.33	0.76	0.71	19.15
Animal/wet dog	0.74	1.39	1.27	16.53
Cooked cereal	2.07	1.75	1.42	14.48
Astringent	1.41	1.79	1.98	12.31
Dairy	0.93	0.64	0.53	11.04
Earthy	0.85	1.24	1.15	10.43
Brothy/meaty	0.86	1.29	1.36	10.25
Bitter taste	1.17	1.46	1.67	8.28
Grainy/starchy	2.49	2.27	1.89	7.57
Cardboardy/musty	1.17	1.52	1.50	6.43
Beany	1.12	1.48	1.21	5.75
Grassy/greenbean	0.56	0.54	0.30	4.74
Sweet aromatic	1.00	0.76	1.08	2.17
Eggy/sulfury	0.59	0.77	0.80	2.09
Sour/acidic	1.03	1.26	1.26	2.00
Rancid/oxidized	0.85	1.01	1.11	1.63
Hulls/woody	1.18	1.37	1.24	1.43
Water-like/metallic	1.32	1.27	1.54	1.34
Sweet taste	1.14	0.94	1.04	1.23
Nutty	1.32	1.46	1.18	1.19
Bran/hay/straw	1.40	1.57	1.39	1.08
n	14	4	4	

Flavor attributes are ranked according to *F* value.

Ward's Cluster Analysis

Ward's cluster analysis resulted in three clusters with a semipartial R^2 of 0.664. The partialing between cluster 1 and the other clusters explains 25.9% (based on pseudo *F* test) times more of the data variation than by chance (5%). Meanwhile, the partialing between cluster 2 and 3 explains an additional 18.8% (based on pseudo *F* test) times more of the data variation than by chance alone (5.3%). Cluster 3 consists of black bran rice cultivars, cluster 2 consists of the red bran rice cultivars and the white, light-brown and brown bran rice cultivars generated cluster 1. The partialing of cluster 1 from cluster 2 and 3 had a semipartial R^2 of 0.564. The partialing of clusters 2 and 3 had a semipartial R^2 of 0.10. This indicated that the black bran rice is not as different from the red bran rice as they were both different from the brown, light-brown and white bran rice. Table 4 lists the means of the clusters with *F* values noted. Larger *F* values indicate which flavor attributes had greater differences between means. The black bran rice samples were more intense in darkberry, smoky/burnt, medicinal, oily, astringent, brothy/meaty and bitter taste. The red bran rice samples were more intense in animal/wet dog, earthy, cardboard/musty and beany taste. In addition, the red bran rice samples are fairly high in smoky/burnt, oily, cooked cereal, astringent, brothy/meaty, bitter and grainy/starchy flavors. The white to brown bran rice samples are more intense in corn/popcorn/buttery, cooked cereal, dairy and grainy/starchy flavors. Cardboardy/musty was higher in red and black bran rice samples than in brown to white. The flavor attribute means for sweet aromatic, eggy/sulfury, sour/acidic, rancid/oxidized, hulls/woody, water-like/metallic, sweet taste, nutty and bran/hay/straw were not different between the three clusters; although there were significant differences between rice sample means for the flavors sweet aromatic, eggy/sulfury, hulls/woody, water-like/metallic, sweet taste, nutty and bran/hulls/woody (Table 5). Rancid/oxidized and sour/acidic were attributes that did not differentiate the rice samples. These two attributes either do not vary between rice samples or, more likely, the panelists need more experience at differentiating these flavors in rice samples. Based on the low correlation (−0.13) in Table 3, the panelists did not seem to confound the two attributes. The rice sample

TABLE 5. MEAN COMPARISON OF FLAVOR ATTRIBUTES BETWEEN ALL RICE SAMPLES

Rice sample	G/S	CK CER	SWT AR	CRN/POP	NUT	B/H/S*	HL/WD†	Oily	DRKBRY	Dairy	Beany	G/GB	BR/MTY
White 1	2.47a	2.30a	0.92abc	1.60ab	0.97ab	1.55a	0.67a	0.92bcdef	0.20d	1.10abc	0.97abcde	0.83abc	0.75bcd
White 2	2.31a	1.96abcd	0.88abc	0.88bcd	1.12ab	1.56a	0.95a	0.61def	0.25d	1.17ab	1.24abcd	0.38abcd	0.64cd
White 3	2.44a	2.19abc	0.69c	1.53ab	1.61ab	1.62a	1.11a	1.44abc	0.50d	0.50cd	0.86de	0.39abcd	1.30abc
Light brown 1	2.63a	2.34ab	0.93abc	0.97bcd	1.13b	1.26a	1.14a	0.40f	0.12d	1.27a	1.13abcde	0.57abcd	0.86bcd
Light brown 2	2.78a	2.09abcd	0.80bc	1.44ab	1.78a	1.63a	1.13a	0.79cdef	0.38d	0.95abc	1.05bcde	0.45abcd	1.33abc
Brown 1	2.38a	2.09ab	1.44abc	1.35abc	1.73ab	1.43a	1.31a	0.88bcdef	0.31d	1.06ab	1.31abcde	0.85ab	0.44d
Brown 2	2.23ab	1.79abcd	1.06abc	1.51ab	1.35ab	1.81a	1.69a	0.60def	0.54d	0.75abcd	1.31abcde	0.60abcd	0.63cd
Brown 3	2.80a	1.91abcd	1.31ab	1.69a	1.10b	1.28a	1.56a	0.66cdef	0.25d	1.00abc	1.06abcde	0.41abcd	0.81bcd
Brown 4	2.54a	2.13ab	0.69bc	1.39abc	1.29ab	1.35a	1.00a	0.88bcdef	0.66cd	0.50cd	1.06abcde	0.25cd	0.94bcd
Brown 5	2.19ab	1.42de	1.56a	1.44abc	1.61ab	1.30a	1.42a	0.67def	0.22d	0.67bcd	0.78e	0.81a	0.89bcd
Brown 6	2.06ab	1.91abcd	1.44abc	1.59ab	1.31ab	1.45a	1.48a	0.63cdef	0.25d	0.88abc	0.98bcde	0.63abcd	0.56cd
Brown 7	2.66a	2.29a	1.14abc	1.64ab	1.06ab	1.19a	1.06a	0.81bcdef	0.31d	0.69abcd	0.81cde	0.73abc	0.88bcd
Brown 8	2.63a	2.27ab	0.64c	1.02bcd	1.13ab	1.08a	0.94a	0.50ef	0.18d	0.88abc	1.43abc	0.60abc	0.87bcd
Brown 9	2.43a	2.12abc	1.01abc	1.42ab	1.23ab	1.33a	1.28a	0.80cdef	0.12d	1.26a	1.27abcde	0.62abc	0.87bcd
Red 1	2.27a	1.71abcd	0.92abc	0.77cd	1.41ab	1.59a	1.44a	1.13bcd	1.76b	0.43cd	1.55a	0.55abcd	1.43ab
Red 2	2.13ab	1.59cde	0.61c	0.74cd	1.53ab	1.58a	1.64a	1.49ab	1.49b	0.52cd	1.31abcde	0.43abcd	1.39ab
Red 3	2.37a	1.73abcd	0.79bc	0.77cd	1.38ab	1.44a	1.11a	1.30abc	1.66b	0.86abc	1.54ab	0.69abc	1.14abcd
Red 4	2.34a	1.95abcd	0.73bc	0.78cd	1.53ab	1.69a	1.27a	0.97bcde	1.39bc	0.79abcd	1.52ab	0.49abcd	1.19abc
Black 1	2.11a	1.49de	0.95abc	0.64d	0.86b	1.49a	1.00a	1.59ab	3.17a	0.58cd	1.04abcde	0.19d	1.71a
Black 2	1.89ab	1.64bcde	1.29ab	0.68d	1.09ab	1.44a	1.20a	1.52ab	3.29a	0.75bcd	1.14abcde	0.32bcd	1.25abc
Black 3	1.53b	1.03e	0.97bc	0.71d	1.18b	1.40a	1.34a	1.35abc	3.15a	0.29d	1.37abcd	0.26cd	1.15abcd
Black 4	2.25ba	1.75abcde	1.16abc	0.91bcd	1.89a	1.13a	1.50a	1.98a	3.10a	0.63bcd	1.31abcde	0.56abcd	1.38abc

Rice sample	CRD/MSTY	Earthy	EG/SF	AN/WD	MEDC	SM/BRN	RAN/OX	SR/AC	SWT TST	BIT TST	WL/MET	AST
White 1	1.33abcd	0.50bcd	0.42ab	0.33f	1.00abc	0.38def	0.80a	0.72a	0.88bcde	1.35abcde	1.93a	1.75abc
White 2	1.46abc	0.57d	0.46ab	1.11abcde	0.64cd	0.57cdef	0.79a	1.07a	1.21bcd	0.92de	1.34abcd	1.21c
White 3	1.26abcd	1.06abcd	1.00a	1.28abcd	0.81bcd	0.33ef	1.17a	1.14a	0.78de	1.44abcde	1.33bcde	1.41bc
Light brown 1	0.72d	0.61cd	0.47ab	0.75cdef	0.40cd	0.39def	0.59a	0.93a	1.00bcde	0.93de	1.52abcd	1.29c
Light brown 2	1.33abcd	0.80abcd	0.78ab	0.89bcdef	0.47cd	0.97abcde	0.92a	1.00a	1.34bcde	0.90e	1.44abcd	1.59abc
Brown 1	1.34abcd	1.04abcd	0.60a	0.54def	0.44cd	0.48def	0.79a	0.90a	1.41bcde	1.48abcde	1.44abcde	1.23c
Brown 2	1.31abcd	1.31abc	0.54a	0.69cdef	0.25d	0.38def	1.13a	0.75a	1.20bcde	1.25abcde	0.66e	1.79abc
Brown 3	0.81d	0.75dc	0.25b	0.41ef	0.25d	0.38def	0.86a	1.14a	0.79cde	1.13bcde	0.88de	1.23c
Brown 4	1.16abcd	0.69cd	0.69ab	0.90abcdef	0.31cd	0.48cdef	0.54a	0.81a	0.98bcde	1.50abcde	1.04bcde	1.18c
Brown 5	1.11bcd	1.06abcd	0.22b	0.50ef	0.70cd	0.53cdef	0.89a	1.29a	1.00cde	1.28bcde	1.17bcde	1.39bc
Brown 6	1.06cd	1.00bcd	0.56ab	0.88bcdef	0.75cd	0.63cdef	0.75a	1.25a	2.16a	1.30abcde	1.00cde	1.56abc
Brown 7	1.16abcd	0.98abcd	0.40ab	0.31f	0.29cd	0.44cdef	0.64a	1.15a	1.09bcde	1.21bcde	1.44abcd	1.60abc
Brown 8	1.35abcd	1.02abcd	0.77a	0.77cdef	0.53cd	0.17f	1.07a	1.23a	0.75e	1.27abcde	1.41abcd	1.45abc
Brown 9	1.04cd	0.75bcd	0.79a	0.54def	0.30d	0.23ef	0.90a	0.88a	1.40bc	1.07cde	1.49abc	1.33bc
Red 1	1.22abcd	1.18abcd	0.93a	1.44ab	0.83bcd	1.31ab	1.03a	1.24a	0.71de	1.51abcd	1.31abcd	1.73abc
Red 2	1.71ab	1.42a	0.75ab	1.32abc	0.94bc	1.56a	1.25a	1.50a	1.04bcde	1.51abcd	1.05cde	1.76abc
Red 3	1.73a	1.34ab	0.80a	1.63a	1.01abc	1.16abcd	0.91a	1.29a	1.08bcde	1.25abcde	1.42abcd	1.76abc
Red 4	1.43abcd	1.03abcd	0.59ab	1.16abcde	0.69cd	0.91bcde	0.84a	1.00a	0.93bcde	1.56abc	1.31abcd	1.91ab
Black 1	1.51abc	1.04abc	0.68ab	1.44abc	1.45a	1.68a	1.02a	1.34a	0.83bcde	1.56abc	1.74ab	1.99ab
Black 2	1.71a	0.99abcd	1.00a	1.37abc	1.46a	1.63a	1.20a	1.32a	0.72cde	1.79ab	1.49abcd	1.97ab
Black 3	1.53abcd	1.33abc	0.74ab	1.09abcde	1.39ab	1.52ab	0.98a	1.18a	1.53ab	1.92a	1.54abcd	2.04a
Black 4	1.04cd	1.25abcd	0.81ab	1.19abcde	1.15abc	1.31abc	1.38a	1.20a	0.91bcde	1.09cde	1.29abcde	1.81abc

a–f Least square mean comparison signifies means within a flavor attribute with the same letter are not different.

* Brown 8 is different from Brown 2, Red 4, Red 1 and Light brown 2. Red 4 is different from Black 4.

† Brown 8 is different from Brown 2, Red 2 and Red 1. Red 2 is different from Red 3 and White 1.

G/S, grainy/starchy; CK CER, cooked cereal; SWT AR, sweet aroma; CRN/POP, corn/popcorn/buttery; NUT, nutty; B/H/S, bran/hay/straw; HL/WD, hulls/woody; OILY, oily(waxy/soapy); DRKBRY, darkberry; DAIRY, dairy; BEANY, beany/lentils; G/GB, grassy/green bean; BR/MTY, brothy/meaty; CRD/MSTY, cardboard/musty; EARTHY, earthy; EG/SF, eggy/sulfury; AN/WD, animal/wet dog; MEDC, medicinal; SM/BRN, smoky/burnt; RAN/OX, rancid/oxidized; SR/AC, sour/acidic; SWT TST, sweet taste; BIT TST, bitter taste; WL/MET, water-like/metallic; AST, astringent.

means in Table 5 show the minimum and maximum means for rancid/oxidized and sour/acidic to be quite different (range from 1.38 to 0.54 and 1.50 to 0.72, respectively), but the variation around the means are too large to be significantly different. Sweet aromatic, eggy/sulfury, nutty, sweet taste and water-like/metallic had significantly different means between rice samples (Table 5) but were not flavors associated with bran color. These flavors are likely associated with production conditions, cultivar or storage conditions rather than bran color.

Effects of Rice Sample on Flavor

Table 5 lists the average scores for the attributes for each rice sample. Rice with black bran was typically lower in grainy/starchy than the other rice samples, but samples labeled Black 2 and 3 were the lowest in grainy/starchy. With the exception of sample Brown 5, and possibly Brown 3, the white, light-brown and brown bran samples are more intense in cooked cereal than the red or black bran samples. Except for samples Brown 4 and Brown 8, sweet aromatic was more intense in the brown bran samples than in the white, light-brown or red bran samples. Corn/popcorn/buttery flavor was highest in brown, light-brown and white bran samples, with the exception of samples White 2 and Light brown 1, and lowest in the black and red rice samples. The scented rice samples in the set were Black 4, Brown 5, Brown 6, Brown 7 and Light brown 2. The Black 4 and Light brown 2 had the highest corn/popcorn/buttery flavor in their respective bran color classes. Nutty flavor was typically high in the red rice samples, as well as in many of the brown, light-brown and white bran samples. This term, commonly used to describe whole-grain rice, was significantly more intense in Black 4 and Light brown 2 than in Light brown 1, Brown 3 and Black 3. Oily flavor is highest in the black rice samples, but it is also, high in White 1, Red 2 and Red 3. Darkberry flavor is very low in all the brown, light-brown and white bran samples and is highest in the black bran samples. The rice with red bran was typically higher than the brown bran rice for medicinal and smoky/burnt and generally higher than the light-brown bran for medicinal. Bitter taste was generally lower in the light-brown bran rice samples and White 2 than the other rice samples. Astringency was lowest in White 2, Light brown 1, Brown 3 and Brown 4. Astringency was more intense in the Black, Red and Brown 2 samples.

CONCLUSION

The information in this paper describes new flavor attributes for whole-grain rice. It also describes the flavor differences in rice samples with various bran colors. Grainy/starchy, cooked cereal, corn/popcorn/buttery and dairy had the highest flavor intensity in rice with white, brown and light-brown bran. Rice with red bran had the highest intensity of beany, cardboard/musty, earthy and animal/wet dog taste. The attributes with the highest taste intensities for rice with black bran were oily, darkberry, brothy/meaty, medicinal, sweet aromatic, smoky/burnt, astringency and bitterness. The rice with black and red bran were both higher in intensity than brown, light-brown and white bran rice for medicinal, oily, brothy/meaty and cardboardy/musty characteristics. This new lexicon will help researchers, breeders and marketers with characterizing the flavor of healthful whole-grain pigmented rice cultivars.

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